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THERMAL POWER AND THE COST OF WASTE HEAT TREATMENT

Federal Water Pollution Control Administration
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United States Department of the Interior
Federal Water Pollution Control Administration
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THERMAL POWER AND THE COST OF WASTE HEAT TREATMENT

Introduction

Large-scale thermal power generation has come to the Pacific Northwest. Even with development of all the additional hydropower sites in prospect, some 15 nuclear-fueled power plants must be built and put into operation from 1974 to 1987 to meet power demands, according to the Bonneville Power Administration's 20-Year Advance Program report released in November 1967. Resources exist for one fossil-fueled power plant--under construction near Centralia, Washington--but the remainder of the demand must be met with nuclear plants.

Under present technology, thermal nuclear power plants convert into kilowatts only one-third of the energy of the nuclear fuel. The remaining two-thirds becomes waste heat which must somehow be disposed of. Depending on how waste heat is handled, there is presented the possibility of far-reaching, adverse impacts on the aquatic environment, particularly water quality. Technology has provided the facilities to assure no adverse environmental impacts. The question most often raised in regard to the use of such facilities is their cost.

Cost information is available, in general terms at least, on the basic power plant and the several alternatives for handling waste heat. What has been lacking is an analysis pointed toward interpretation of cost information presently available in such a way as to evaluate the impact of waste heat treatment costs on the cost of power to consumers when new thermal nuclear power plants are integrated into an ongoing company system. In short, would the installation of waste heat treatment

require a significant increase in consumer power bills? The purpose of the analysis presented in this report is to answer that question as conclusively as it can now be answered, using the best data available at this time. The analysis presented attempts to analyze the incremental cost to the consumer of a nuclear-fueled thermal power unit, using Portland General Electric as the example utility, and the added increment to that cost attributable to the installation of a waste heat treatment method. The question of the importance of the resulting competitiveness in power rates between the Pacific Northwest and other regions is also indicated.

Summary of Conclusions

The findings of the analysis, in general, are subject to some variations in absolute terms, but the incremental costs and comparisons are considered sufficiently valid to allow reasonable judgments in regard to the Portland General Electric example system. A 1,000 MW nuclear plant with once-through cooling (when integrated into its present system) would decrease Portland General Electric consumer costs below their present levels in a range from 1.9 percent for commercial consumers to 3.5 percent for industrial consumers. The most expensive waste heat treatment method analyzed, the natural draft wet cooling tower, would cause an insignificant increase over the Portland General Electric consumer costs of 1966, ranging between 0.1 and 0.2 percent. The waste heat treatment methods analyzed with costs between the above two methods are once-through salt water cooling and induced draft wet cooling towers.

Because annual power bills of Portland General Electric's consumers would be little affected by the most expensive treatment method analyzed,

the question of competitive rates between the Pacific Northwest and utilities in other regions does not arise. However, it is felt that the whole question of cheap power as being vital to economic development should not be exaggerated. The analysis tends to show that those industries depending heavily upon cheap power have decreasing importance as an economy diversifies and matures, and those industries now contributing the most to the economic growth of the Pacific Northwest are not dependent upon cheap power.

Basic Nuclear Plant Costs

Because this analysis assumes an average or typical nuclear plant in contradistinction to a nuclear plant at a particular site and because of relatively fast changes in economic and technical aspects of nuclear power, all cost figures are necessarily only estimates. Considerations that might be pertinent to a specific site study but not considered in this analysis would include costs associated with possible make-up water holding ponds and blowdown water treatment.[1/] Figures presented in this study, then, should be understood to be for illustrative purposes, yielding only orders of magnitude instead of definitive answers.

The cost of a 1,000 MW nuclear plant with once-through fresh water cooling is apparently somewhat higher now than at the time of the incorporation of nuclear proposals in the TVA system or those for the Oyster Creek plant of Jersey Central. The Bonneville cost study gives $160/KW as the capital cost with once-through fresh water cooling.[2/] Interest

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1/ Make-up water ponds at the 1,400 MW coal-fired Centralia plant are estimated to cost $10,000,000.

2/ Letter from John F. Baldino, Acting Administrator, Bonneville Power Administration, to J. L. Agee, Pacific Northwest Regional Director, FWPCA, dated August 26, 1968.

during construction was given as $14.4/KW, making a net of $145.6/KW for the plant alone. Excluding interest during construction, TVA's two Browns Ferry plants capital investment was reported as $105.6/KW ($116 billion for 1,098 MWs) each.[3/] Battelle-Northwest used $121/KW, excluding interest during construction.[4/] The capital cost of the 815.5 MW Surry plant is given as $153/KW, but the portion of this figure attributable to interest during construction was not separated.[5/]

In deriving annual costs, the Bonneville cost study mentioned above was used, and all cost figures referred to hereafter, unless noted, were taken from that study. An 85 percent load factor with a 35-year life was assumed. Financing was based upon 60 percent bonded debt at a 6 percent rate of interest, 30 percent common stoc .. a 7½ percent rate of interest, and 10 percent preferred stock at a 6½ percent rate of interest. This structure would yield an overall rate of 6.4 percent.

A 1,000 MW nuclear power plant with once-through fresh water cooling will be considered the reference plant with which all other plants with different cooling methods will be compared. The separate cost of the cooling method on this reference plant will not be delineated. Table I illustrates the results of the assumptions for this reference plant.

3/ "Comparison of Coal-Fired and Nuclear Power Plants for the TVA System," Office of Power, TVA, Chattanooga, Tennessee, June 1966. Table 1, p. 4, BWR Type.

4/ Battelle-Northwest. Nuclear Power Plant Siting in the Pacific Northwest. BPA Contract No. 14-03-67868, July 1, 1968, Summary Report, p. 43, Figure 4.

5/ Nuclear Power Economics--1962 Through 1967. Report of Joint Committee on Atomic Energy, 90th Congress, 2d Session, February 1968, p. 20, Table III.

TABLE I*
COST SUMMARY OF
1,000 MW NUCLEAR PLANT
WITH ONCE-THROUGH COOLING

Total Annual Production (KWH x 10^9)	7.446
Total Plant Capital Cost ($000)	160,000
Fixed Annual Cost ($000)	23,715
Variable Annual Cost ($000)	8,610
Total Annual Generator Terminal Cost ($000)**	32,325
Mills/KWH	4.34

* Source: Letter from John F. Baldino, op. cit.
** Equals bus-bar costs minus step-up transformers and circuit breakers estimated at $375,000 annually.

Thermal Treatment Costs

The treatment of thermal power waste heat is relatively new to the American scene, and lack of data is even more noticeable than for nuclear plants. Just the number of methods for waste heat dissipation alone make a definitive cost study difficult. These methods range from once-through fresh and salt water to cooling ponds to wet and dry cooling towers, natural or induced draft. Each type of cooling tower can be constructed several ways to yield a given result. And, of course, each method has construction and operating costs different from those of another method. The same technological and economic factors met in regard to nuclear plant costs above compound the problem.

In conducting a general anaylsis of waste heat treatment cost, it is important to point out that only reference or illustrative plants can be handled. To be truly representative, a study would have to be conducted

relative to specific sites. There is a potentially large cost difference between sites. A specific site may exclude a wide choice of thermal treatment methods because of topography, because of former areal development, or because of climatic conditions. For instance, cooling ponds are reported to be doubtful at Portland General Electric's Trojan site because the topography and former land development would appear to forego them. Dry-type towers are doubtful east of the Cascades because of climatic conditions during the warmest period of the year, a time when thermal treatment is most needed. Atmospheric conditions in some locations may preclude wet cooling tower operations at times.

Transmission costs are another item requiring specific site analysis. Thermal treatment requirements may necessitate a different site selection that might increase transmission costs.

For illustrative purposes, four types of cooling methods were selected--once-through fresh water (incorporated in the reference plant), once-through salt water, induced draft wet cooling towers, and natural draft wet cooling towers. All were analyzed with the same financial structure as was assumed for the 1,000 MW reference nuclear plant with once-through fresh water cooling. Table II presents the capital cost (including interest during construction) and total annual cost of each method as increments to the reference nuclear plant.

TABLE II*
INCREMENTAL CAPITAL AND ANNUAL COSTS
OF WASTE HEAT TREATMENT METHODS

Treatment Methods	Millions of Dollars	
	Capital Cost	Total Annual Cost
Once-Through Fresh Water	(Not delineated)	
Once-Through Salt Water	7.9	0.96
Induced Draft Wet Cooling Towers	8.0	1.34
Natural Draft Wet Cooling Towers	13.8	2.00

* Source: Letter from John F. Baldino, op. cit.

As the table shows, natural draft wet cooling towers have not only the highest incremental capital cost of those analyzed but also the highest incremental annual cost.

There are other cooling methods. Fan-assisted natural draft hyperbolic wet cooling towers are a possibility, but the lack of sufficient data at this time prevented an analysis. Cooling ponds are also possible, but the analysis of a typical cost situation in the absence of a specific site and land costs proved impractical. Other types of treatment include the dry-type cooling methods. However, dry-type cooling methods are probably unsatisfactory in most areas and were excluded from the analysis.

Merger with PGE System

With the above discussion of nuclear plant and thermal treatment costs, a 1,000 MW nuclear power plant can be merged with any utility system. Portland General Electric's present system will be used as an example. Such a plant will more than double Portland General Electric's presently available KWH's from 6.4 billion to approximately 13.8 billion KWH annually. The following table summarizes these mergers.

TABLE III
1,000 MW NUCLEAR PLANT
MERGED WITH PGE SYSTEM

	1966[A/] Actual	Once-Through Fresh Water	Once-Through Salt Water	Induced Draft Wet Cooling Tower	Natural Draft Wet Cooling Tower
Generation Investment[B/]	$120,049,000	$160,000,000	$167,900,000	$168,000,000	$173,800,000
Annual Expenses:					
Total Generation Expenses	$ 15,804,000	$ 32,325,000	$ 33,285,000	$ 33,665,000	$ 34,325,000
Purchased Power	14,487,000	--	--	--	--
Total Production Expenses	$ 30,291,000	$ 32,325,000	$ 33,285,000	$ 33,665,000	$ 34,325,000
Total Annual Power Production KWH (1,000's)[C/]	6,375,245	7,446,000	7,446,000	7,160,000	7,197,000
Production Cost, Mills per KWH	4.75	4.34	4.47	4.70	4.77
Merged with PGE System:					
Generation Investment		$280,049,000	$287,949,000	$288,049,000	$293,849,000
Total Annual Expenses		$ 62,616,000	$ 63,576,000	$ 63,956,000	$ 64,616,000
Total Annual Power Production KWH (1,000's)		13,821,245	13,821,245	13,535,245	13,572,245
Production Cost, Mills per KWH		4.53	4.60	4.73	4.76

A/ Source: Statistics of Privately Owned Electric Utilities in the United States. FPC S-186; GPO, September 1967, and FPC Form No. 1, 1966, Annual Report to the Federal Power Commission. Total annual generation expenses include generation O&M, generation depreciation, total allocated taxes, and total allocated net income. The latter two were allocated in the same proportion as net generation investment was to total net investment. See Appendix for complete explanation.

B/ PGE's gross generation investment amounted to $138,773,000 with $18,724,000 accumulated depreciation. Nuclear plant investment includes capital cost and interest during construction.

C/ Assumes PGE's actual 1966 sales plus generation capability for nuclear addition at 85% load factor.

The above "Total Production Expenses" does not mean total system expenses, but represents costs of only the generation plant and appurtenant facilities, excluding switch yards and transformers.[6/] As Table III shows, purchased power expenses in 1966 almost equaled Portland General Electric's total generation expenses (92 percent) and accounted for 48 percent of its total production expenses. For the comparative purposes of this analysis, it is assumed the company will continue to purchase the same amount of power in the future. (This restriction is discussed later.) The most noteworthy item in Table III is the decrease in the costs per kilowatt hour of 4.6 percent after the nuclear plant with once-through fresh water cooling is merged with Portland General Electric's system.

The relative cheapness of nuclear power might seem in error since most of Portland General Electric's power source is hydro-generation. However, the list in Table IV of Portland General Electric's power sources (excluding purchased power) strongly indicates the reason for this seeming anomaly. Of the total eleven plants, three are steam, and the majority of the others are small hydro-plants. Because of their small size, they undoubtedly represent high cost power when compared with any large hydro-plant on the main stem Columbia River, for instance.

6/ Production is generally expressed in terms of "bus-bar costs," which includes switch yards and step-up transformers. Since these two items cannot be separated from Portland General Electric's transmission costs, they were excluded from the nuclear plant analysis also.

TABLE IV
PORTLAND GENERAL ELECTRIC'S
PRESENT SOURCE OF POWER

Name	Location	Type	Nameplate Rating KW
Bull Run	Bull Run Creek	Hydro	21,000
Faraday	Clackamas River	"	34,450
North Fork	" "	"	38,400
Oak Grove Fork	" "	"	51,000
Pelton	Deschutes River	"	108,000
Portland 'E'	Portland	Steam	10,000
Portland 'L'	"	"	75,000
River Mill	Clackamas River	Hydro	19,050
Round Butte	Deschutes River	"	247,050
Salem 'H'	Salem	Steam	2,500
Sullivan	Willamette River	Hydro	15,400
Total			622,350

The power sources listed in the above table accounted for approximately 26 percent of the total power sold by Portland General Electric in 1966. Of the total purchased power (74 percent of the total power sold), 46 percent was purchased from the Bonneville Power Administration. An estimate indicates Portland General Electric's purchased power cost them an average of 3.07 mills per KWH while their generated power was in the neighborhood of 9.50 mills per KWH.[7/] Consequently, it is not surprising that the reference nuclear plant manifests smaller costs per KWH.

7/ Total power sold amounted to 6,375,245 MWH. Total power purchased amounted to 4,712,250 MWH costing approximately $14,487,051 yielding 3.07 mills/KWH. They generated from their own power sources, then, 1,662,995 MWH costing $15,804,352 yielding 9.50 mills/KWH. See Appendix.

Effects on Consumers' Costs

The effect of the mergers illustrated in Table III on Portland General Electric's production cost varies from a 4.6 percent decrease in the case of the once-through fresh water method to a 0.2 percent increase in the case of the natural draft wet cooling tower method. Table V presents these percentage changes in production costs.

TABLE V
CHANGES IN PORTLAND GENERAL ELECTRIC'S PRODUCTION COST*
WITH DIFFERENT TREATMENT METHODS

Treatment Methods	Percentage Change in 1966 PGE Production Cost
Once-Through Fresh Water	-4.6
Once-Through Salt Water	-3.2
Induced Draft Wet Cooling Tower	-0.4
Natural Draft Wet Cooling Tower	0.2

* Source: Computed from Table III.

The effect of these production cost changes upon consumer power bills depends upon the proportion of consumer power bills accounted for by production costs. If production costs on a KWH basis amount to 50 percent of the cost of power to the consumer, then any change in production cost will affect consumer costs only one-half as much. The implicit assumption, of course, is that all other costs--transmission, distribution, customer service, administration, etc.--remain the same. Table VI presents the relevant percentage changes in consumer power bills brought about by the merger of the different cooling methods.

What the above percentage changes mean in regard to Portland General Electric's present average consumer charges on a kilowatt hour basis is shown on Table VII.

The changes in consumer charges presented in the two tables depend upon the degree to which Portland General Electric incorporates the new additional power in its system. It was assumed that Portland General Electric would continue to produce as much power from their other generating facilities and to purchase the same amount of power as before. These are restrictive assumptions, since several different alternatives are open to Portland General Electric, and they will likely choose an operating procedure different from that assumed. They could, for instance, terminate a sizable portion of their purchasing contracts and sell the remaining unused new power. Alternately, Portland General Electric could close down their less efficient power sources in combination with a reduction in power purchases.

In any case, Portland General Electric will be able to incorporate in their own system only a minor portion of their nuclear power output regardless of the operating procedure chosen. In such a case, the full effects of changes in production costs should not be passed on to Portland General Electric's consumers. For example, if they could incorporate only 20 percent during the first five years and then some greater percentage five years later, and so on, then only 20 percent of the change in the costs delineated in the above analysis should be passed on to the consumer during the first five years, a larger percentage for the second five years, etc. Since all the output of the nuclear addition was assumed to be incorporated within

TABLE VI
PRODUCTION EXPENSE DISTRIBUTION
PORTLAND GENERAL ELECTRIC

Consumer Class	1966 Alloc. Prod. Cost as % of Consumer Cost*	Percent Change to Consumer from 1,000 MW Merger With... Once-Through Fresh Water[A]	Once-Through Salt Water[B]	Induced Draft Wet Cooling Tower[C]	Natural Draft Wet Cooling Tower[D]
Residential	46.43	-2.1	-1.5	-0.2	0.1
Commercial	41.68	-1.9	-1.3	-0.2	0.1
Industrial	76.62	-3.5	-2.5	-0.3	0.2

* Source: See Appendix A for the derivation of these figures.

A/ First column multiplied by 4.6 percent decrease. See Table V.
B/ First column multiplied by 3.2 percent decrease. See Table V.
C/ First column multiplied by 0.4 percent decrease. See Table V.
D/ First column multiplied by 0.2 percent increase. See Table V.

TABLE VII
EFFECTS OF CHANGE IN PRODUCTION COSTS ON PORTLAND GENERAL ELECTRIC CONSUMER CHARGES
MILLS PER KWH

Consumer Class	1966* Actual	1,000 MW Nuclear Merger With... Once-Through Fresh Water	Once-Through Salt Water	Induced Draft Wet Cooling Tower	Natural Draft Wet Cooling Tower
Residential					
Production Costs	5.225	4.985	5.058	5.204	5.235
All Other Costs	6.029	6.029	6.029	6.029	6.029
Total Consumer Charges	11.254	11.014	11.087	11.233	11.264
Commercial					
Production Costs	5.225	4.985	5.058	5.204	5.235
All Other Costs	7.312	7.312	7.312	7.312	7.312
Total Consumer Charges	12.537	12.297	12.370	12.516	12.547
Industrial					
Production Costs	3.389	3.233	3.281	3.375	3.396
All Other Costs	1.034	1.034	1.034	1.034	1.034
Total Consumer Charges	4.423	4.267	4.315	4.409	4.430

* See Appendix for derivation of these figures.

the Portland General Electric system in the above analysis, it would tend to represent a maximum incremental effect on their consumers.

In 1966 Portland General Electric's average residential consumer used 11,726 kilowatt hours of power and paid $132, their average commercial consumer 47,910 kilowatt hours of power and paid $601, and their average industrial consumer 14,071,410 kilowatt hours of power and paid $62,238. Assuming the same amount of power is used by consumers in the future, and considering the maximum incremental effect, average yearly consumer power bills would be as shown in Table VIII.8/

TABLE VIII
EFFECT OF NUCLEAR*
MERGER ON PGE'S CONSUMERS

		Average Yearly Power Bills After Nuclear Merger With...			
Consumer Class	1966 Actual	Once-Thru Fresh Water	Once-Thru Salt Water	Ind. Draft Wet C.T.	Nat. Draft Wet C.T.
Residential	$ 132	$ 129	$ 130	$ 132	$ 132
Commercial	601	589	593	600	601
Industrial	62,238	60,043	60,718	62,041	62,336

* Consumer cost per KWH from Table VII multiplied times the above annual consumer KWH consumption.

As the above table indicates, the change in production costs associated with the addition of the induced draft wet cooling tower and with the natural draft wet cooling tower, would not be large enough to materially affect consumer power bills. With once-through fresh and salt water cooling,

8/ This implies, of course, that the Portland General Electric system will expand by the necessary number of consumers.

there is a significant decrease in consumer power bills, particularly in regard to industrial consumers. It is again emphasized, however, that the above analysis is only illustrative and not definitive. The analysis assumed a typical or average 1,000 MW nuclear plant in the absence of a particular site.

Power Rates and Pacific Northwest Growth

The question of what the addition of the cost of thermal waste treatment will do to the competitiveness of the Pacific Northwest relative to other areas in attracting heavy power using industries is brought to mind. The question is a valid one but does not appear to have as much importance in the future as it enjoyed in the past, and because power rates will not be affected in regard to Portland General Electric's case, it is more or less an academic question. Nevertheless, it does deserve some comment.

In a broader sense, the forces bringing about economic growth have been undergoing a significant change. In the past, economic development has been largely natural resource oriented. The development of agriculture, forestry, fishing, and mining meant a growing population and rising incomes--particularly agriculture and forestry in regard to the Pacific Northwest. It meant a developing manufacturing base for those products tied closely to their source of raw material. Natural resource orientation is still a relatively important factor in the economic development of the area, but its importance becomes of lesser force as the economy diversifies and matures.

The change has involved a shift from a large dependence upon natural resources and manufacturing tied to natural resources to a greater depen-

dence upon skills and services. Battelle Memorial Institute states the case:

> A fundamental factor in the evolving economic structure is the increasing importance of the human element. More and more businesses are demanding highly skilled and stable labor forces, and industry is locating where the best quality labor is available or can be attracted.9/
>
> . . . .
>
> In the next decade the Pacific Northwest will continue its development into a diversified manufacturing economy. The primary industries of agriculture, lumbering, fishing, mining and metal smelting, will continue to be important employers, but secondary manufacturing activities such as aircraft, electronics and machinery manufacture will represent a more significant source of new employment during the 1970's.
>
> Paralleling this transition will be the increasing importance of service industries as major sources of employment.10/

Historical data indicate this trend to services, machinery and electronics. Employment in the traditional basic industries--agriculture, forestry, fisheries, mining, and manufacturing--increased 38 percent between 1940 and 1960, whereas all service type industries, armed forces excepted, increased some 86 percent. Manufacturing itself increased employment in the Pacific Northwest between 1940 and 1960 about 94 percent, but the machinery employment category of manufacturing increased some 200 percent and the electrical employment category shot up some 700 percent. The growth

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9/ The Pacific Northwest, Economic Growth in a Quality Environment, December 1967, p. 9.

10/ Ibid. p. 11.

of industries based upon skills, education, scientific research, and other factors (including chance) rather than upon natural resources--cheap, hydroelectric power is a natural resource--has been demonstrated in the case of Albany's rare metal's complex and Seattle's transportation developments. The aerospace industry in the Puget Sound alone increased employment from about 60,000 in 1963 to over 90,000 in 1967, an increase of over 50 percent.11/ Omark in machinery and Tektronix and Electronic Specialty in electronics are examples of companies in Portland pushing this trend along.

Among the changes in locational factors listed by Portland General Electric is that, "Electric power rates, except for a few industries, tend to be a low-rated factor in site selection."12/ For Portland General Electric this is undoubtedly true. Those industries locating in the Pacific Northwest because of its cheap power are served by non-private utilities. Even so, those industries should not be over-emphasized in their contribution to economic development of a region. The heavy power using aluminum industry is a case in point. Bonneville Power Administration estimates show that additional employment throughout the entire Pacific Northwest attributable to direct aluminum employment is on the order of 1 to 2 jobs per smelter job.13/ In 1965 direct employment in the aluminum industry in

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11/ Economic Study of Puget Sound and Adjacent Waters. Prepared for Puget Sound Task Force of Pacific Northwest River Basins Commission, Consulting Services Corporation, January 1968, p. 19.

12/ Area Development and Research Forum, Vol. 1, No. 2, November-December, 1967. "The Changing Pattern of Industrial Location Factors," Fred I. Weber, Jr. A Portland General Electric Publication, p. 4.

13/ Aluminum. Pacific Northwest Economic Base Study for Power Markets, U. S. Department of the Interior, Bonneville Power Administration, Vol. II, Part 7B, 1967, p. 273.

the Pacific Northwest was 9,082 and is projected to 17,100 by 1980.[14/] This would mean total direct and indirect employment of 27,200 in 1965 and 51,300 by 1980 (using the maximum multiplier of 3). Comparing this to total employment of approximately 2.0 million in the Pacific Northwest in 1965 and a projection to approximately 2.9 million by 1980, tends to place the aluminum industry with its high power requirements in proper perspective. Whereas the aluminum industry's power requirements in 1965 equaled 21 percent of the total power requirement of the Pacific Northwest (projected to about 23 percent by 1980), it directly and indirectly employed only 1.4 percent of the Pacific Northwest's total employed work force (projected to about 1.8 percent by 1980).

Actually, Portland General Electric is very competitive with utilities in other regions in the United States. Table IX illustrates this competitiveness.

TABLE IX
U.S. AVERAGE CONSUMER CHARGES*
Mills per KWH, 1966

	Industrial	Commercial	Residential
American Power	7.74	19.81	19.72
Commonwealth Edison of Ill.	9.91	21.87	26.84
Georgia Power	8.46	19.48	17.01
Los Angeles, Dept. of W & P	8.60	12.92	20.12
San Antonio, City Pub.Sv.Bd.	10.01	21.24	21.03
Southern California Edison	8.74	17.87	23.88
Texas Electric Service	9.78	18.83	23.55
T.V.A.	4.16	-	-
Portland General Electric	4.42	12.54	11.25
U.S. Average	9.78	21.29	23.40

*Source: Statistics of Privately Owned Electric Utilities in the United States, FPC S-186, GPO, September 1967, and Statistics of Publicly Owned Electric Utilities in the United States, FPC S-188, GPO, November 1967.

14/ Ibid, p. 274

As shown, TVA is the only utility with cheaper average industrial rates. In terms of the Pacific Northwest, however, Portland General Electric's competitive stance is less noteworthy. Table X illustrates this comparison.

TABLE X
PACIFIC NORTHWEST*
AVERAGE CONSUMER CHARGES
Mills Per KWH, 1966

	Industrial	Commercial	Residential
B.P.A.	2.06	-	-
Clark County PUD	3.85	10.18	9.03
Eugene W. & E. B.	2.84	7.94	8.69
Idaho Power	5.13	13.17	17.50
Montana Power	6.34	18.90	20.91
Pacific Power & Light	7.49	16.08	14.20
Puget Sound P & L	6.34	17.43	12.11
Seattle City Light	5.02	11.29	9.03
Snohomish County PUD	4.10	12.08	8.49
Washington Water Power & Light	6.27	14.77	13.64
Portland General Electric	4.42	12.54	11.25

* Source: Same as for Table IX.

These figures are somewhat deceptive as a comparison in that Clark County PUD, Eugene W. & E. B., and Snohomish County PUD are very small (KWH sales one-fourth PGE's) and bought practically all their power from the Bonneville Power Administration. As shown, the Bonneville Power Administration is the only major utility with average industrial rates below Portland General Electric's average industrial rates. The merger of a nuclear plant having

differing cooling methods with Portland General Electric's system would change their average industrial rates ranging from approximately 4.3 mills/KWH in the case of the once-through fresh water method to approximately 4.4 mills/KWH (about the same as their present rates) in the case of the natural draft wet cooling tower method.15/ Consequently, Portland General Electric's competitive stance with other utilities in other regions of the United States and in the Pacific Northwest will not be materially affected.

Conclusion

Although the cost data on the coming nuclear fueled thermal generating units and assumed waste heat treatment methods are of necessity only estimates of reference plants, the above analysis is believed to have sufficient validity to allow a reasonable judgement as to their effect upon consumer power bills. In the case of Portland General Electric, the addition of the basic nuclear plant with once-through cooling would show a decrease in power costs. However, by adding the most expensive method analyzed, the natural draft wet cooling tower, Portland General Electric consumers would remain in about their present cost position.

Cheap power is always a favorable factor in helping to develop and broaden the economic base of an economy. There are many theories on the cause and effect of economic development, and many factors contribute to economic growth--natural resource endowment, size of population, education of population, climate, cultural development, political goals, etc., all factors interacting with each other. Given these factors, however, the development of a cheap power source could be a strong factor in setting

15/ See Table VII.

off a chain reaction leading to the development of a relatively undeveloped area. Whereas an area was formerly dependent largely upon agricultural and forestry industries (as was true of the Pacific Northwest), cheap power could induce the development of electro-processing industries and broaden that area's economic base to some extent (make the growth of the area less dependent upon the growth of agriculture and forestry, in the case of the Pacific Northwest).

Whatever sets off this chain reaction (and it need not necessarily be cheap power although cheap power would certainly play some part), one can see that, as more and more different-type industries develop, the economy of the area becomes less and less dependent upon the contributions of any one industry, though never completely independent of that industry.

This in no way implies that the growth of the Pacific Northwest depended upon the development of cheap power. In all probability, even without cheap power the Pacific Northwest would have developed at a faster rate than was true of the Nation but, without a doubt, the growth was accelerated to some unknown extent because cheap power was developed.

As pointed out, the industries presently making the greatest contribution to the growth of the economy of the Pacific Northwest are not dependent upon cheap power.

APPENDIX

APPENDIX
Production Cost
Portland General Electric's
Present System
1966

Portland General Electric's production cost analysis could not be extracted in a direct manner from published reports. Two assumptions were necessary: To derive the portion of total taxes and net income allocated to production expenses, it was assumed that both would be allocated in the same proportion as net generation investment was of total net investment. Table I below presents total production costs of Portland General Electric's system with the above assumptions.

TABLE I
PORTLAND GENERAL ELECTRIC
PRODUCTION EXPENSES
1966

	Dollars*
Total Generation Operations and Maintenance	$ 1,809,019
Generation Depreciation	648,035
Allocated Taxes (40.25% of Total Taxes)	4,667,590
Allocated Net Income (40.25% of Total Net Income)	8,679,708
Total Generation Expenses	$15,804,352
Purchased Power	14,487,051
Total Production Expenses	$30,291,403
Total Power Sold, 1,000's of KWH	6,375,245
Production Cost, Mills Per KWH	4.751

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* Source: Statistics of Privately Owned Electric Utilities in the United States, 1966. FPC S-186, GPO, September 1967, and FPC Form No. 1, Annual Report to the Federal Power Commission, 1966. All other figures presented in this appendix was derived from the above publications.

Normally, the above production expenses would be allocated to consumers in the same proportion as their total kilowatt hour consumption is to total power sold. However, since the production cost on a KWH basis comes to 4.751 mills whereas the average industrial consumer paid only 4.423 mills, some additional costs have to be carried by other than industrial consumers. It was assumed, then, that industrial consumers contributed nothing to present net income, that power was sold to industrial consumers at cost.

Consequently, the allocation of production costs to Portland General Electric's consumers was carried out in two steps. Costs were first allocated ex-anti net income in the same proportion each consumer class' power consumption was of the total power sold, then net income was distributed to all but industrial consumers. Table II below presents the production cost distribution ex-anti net income, and Table III the net income distribution.

TABLE II
DISTRIBUTION OF PRODUCTION
EXPENSES EX-ANTI NET INCOME

Consumer Class	Thousands of KWH's	Percent of Total Production Cost*
Total Sold	6,375,245	100.00
Residential	3,070,029	48.16
Commercial	1,541,217	24.18
Industrial	1,646,355	25.82
Other	117,644	1.85

* Derived by dividing power consumed by each consumer class by the total power sold.

TABLE III
NET INCOME DISTRIBUTION

Consumer Class	Percent of KWH Consumed	Percent of Total Distributed*
Residential	48.16	64.91
Commercial	24.18	32.59
Other	1.85	2.49
Total	74.19	

* Derived by dividing each consumer class by 74.19.

Residential consumers would be assigned 48.16 percent of the production cost ex-anti net income and 64.91 percent of net income, etc.

The above analysis, together with the production expense table (Table I), would yield a total production cost distribution to the different consumer classes as follows (the "other" consumer class will be dropped):16/

TABLE IV
TOTAL PRODUCTION COST
DISTRIBUTION BY CONSUMER CLASS
PORTLAND GENERAL ELECTRIC
1966

Consumer Class	Excluding Net Income	Net Income	Total Allocation
Residential	$10,408,192	$ 5,633,998	$16,042,190
Commercial	5,225,708	2,828,717	8,054,425
Industrial	5,580,140	0	5,580,140

A completed picture of the above analysis showing the relevant KWH's and costs is shown in Table V.

16/ The "other" consumer class includes railroads, public streets and highways, and other public authorities.

TABLE V
PRODUCTION COST BY
CONSUMER CLASS
1966

Consumer Class	KWH	Dollars	Mills/KWH
Residentials, 1,000's of KWH sold	3,070,029		
Allocated Production Cost		$16,042,190	
Mills Per KWH			5.225
Residential Revenues (power bills)		34,551,189	
Mills Per KWH			11.254
Percent Production Cost of Consumer Cost			46.43
Commercials, 1,000's of KWH sold	1,541,217		
Allocated Production Cost		8,054,425	
Mills Per KWH			5.225
Commercial Revenues (power bills)		19,322,109	
Mills Per KWH			12.537
Percent Production Cost of Consumer Cost			41.68
Industrials, 1,000's of KWH sold	1,646,355		
Allocated Production Cost		5,580,140	
Mills Per KWH			3.389
Industrial Revenues (power bills)		7,281,589	
Mills Per KWH			4.423
Percent Production Cost of Consumer Cost			76.62

From Table V, it can be seen that total allocated production costs accounted for 46.4 percent of residential power charges; for commercial consumer, total allocated production costs represented 41.7 percent of total commercial

charges. Total allocated production costs for industrial consumer, however, amounts to 76.6 percent of total industrial charges, reflecting the result of the reallocation of net income.

Normal net income on the 1,000 MW nuclear plant was distributed equally (in percentage terms) when it was merged with the Portland General Electric system, however. There are two reasons for this dichotomy in the analysis. First, the analysis of the costs of the nuclear plant and of the different waste treatment methods as received from Bonneville Power Administration made it impossible to separate the net income component without completely reworking the computations. Second, the equal distribution of net income of the nuclear addition would reflect a maximum incremental effect upon industrial consumers. Since competitive industrial power rates in the Pacific Northwest are developing into an important issue, it was felt that relaxing the "non-uniform distribution of net income" in regard to the nuclear merger would allow a margin of safety. To be consistent would require the same "two-step" analysis as was done in analyzing Portland General Electric's present status. Using the "two-step" analysis, industrial consumer rates would have been somewhat lower than the analysis in the main report shows and residential and commercial consumer rates somewhat higher.